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Nutritional and microbial evaluation of some frozen marine fish species sold in selected local government areas of Kano State, Nigeria

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ABSTRACT. This study was carried out to evaluate the nutritional compositions and microbial load of some frozen marine fish species sold in Kano State, Nigeria. A total of 81 samples comprising 27 each of Atlantic herring (*Clupea harengus)*, Atlantic mackerel (*Scomber scombrus*) and Atlantic horse mackerel (*Trachurus trachurus*) were purchased from three sampling areas: Bichi, Dambatta and Gwarzo. They were analysed for proximate, mineral compositions, and microbial load using standard procedures. Results indicated that the highest crude protein content, 21.51% was recorded in *T. trachurus* from Dambatta, while the mineral composition revealed that *C. harengus* recorded the highest sodium content, 1.69 mg Kg^{-1}, from Bichi. The highest free fatty acids 2.07 ± 0.18% was observed in *T. trachurus* from Gwarzo. The results of the microbial population elucidated that *T. trachurus* had the highest *Salmonella spp.* count of 4.22 x 10^6cfu g^{-1} from Dambatta. The *Escherichia coli* of 3.22 x 10^6cfu g^{-1} recorded in *S. scombrus* from Dambatta was the highest. All the microbial loads parameters were affected by the species, but not the collection station. The microbial load recorded in this study did not exceed the recommended limit of x10^6 to 10^7cfu g^{-1} of bacteria load safe for human consumption. The study therefore recommends *T. trachurus* as the best for consumption in the study area, due to its higher protein composition and the lowest microbial load.

Keywords: marine fish; frozen; proximate; minerals; microbial loads; free fatty acids.

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Introduction

Aquatic food system strategies can help address the complex issue of the 'triple burden of malnutrition': food insecurity, undernutrition and overweight (Food and Agriculture Organization, 2020). Many coastal and inland populations rely on these aquatic foods as the most accessible source of animal protein. Aquatic foods include finfish, crustaceans, molluscs and aquatic plants such as seaweed. Fish is a cornerstone of diets around the world, recognised for its nutritional benefits. According to Li et al. (2021), fish is a major source of protein, providing essential amino acids for the maintenance of body tissues, rich in essential fatty acids, particularly omega-3 fatty acids, which are important for reducing inflammation, supporting heart health, and promoting brain function. Fish also supplies vital vitamins such as vitamins D and B-complex, as well as minerals like iodine, selenium, and zinc (Awuchi et al., 2020).

The global demand for seafood continues to rise, driven by increasing awareness of its health benefits and a growing population. Marine fish, in particular, are renowned for their rich nutritional profiles, including omega-3 fatty acids, which are crucial for cardiovascular health and cognitive function (Durmuş, 2018). Marine fish, which are often distributed in frozen form, are particularly valued for their nutrient density. However, the nutritional quality and microbial safety of frozen marine fish can be affected by several factors throughout the supply chain; improper handling and storage can lead to nutrient degradation and microbial proliferation, posing health risks to consumers (Chakma et al., 2020). Therefore, it is essential to regularly evaluate these parameters to ensure consumer safety and maintain public confidence in marine fish products.

In Nigeria, fish constitutes a major part of the diet for many people, contributing significantly to food security and nutrition. According to Olaifa et al. (2022), fish is not only a dietary staple but also an economic commodity, contributing to livelihoods through fishing, processing, and trading activities. Kano State, located in Northern Nigeria, is a major hub for the distribution of frozen marine fish due to its strategic position and large population. The local markets and retailers in various Local Government Areas (LGAs) of Kano State play a crucial role in ensuring the availability of these essential food items. However, the quality and safety of frozen marine fish can be compromised due to several factors, including handling and storage conditions, which are usually different from one station/outlet to another. The handlings and storage conditions might influence the microbial contamination and other spoilage processes (Chakma et al., 2020).

Food safety has recently become a catchphrase, thanks to rising consumer knowledge of the ill effects of consuming substandard food and the role of independent media as ombudsmen (Geetha et al., 2016). Understanding the nutritional content and microbial safety of frozen marine fish is vital for public health, as it ensures that the fish consumed meets the necessary standards for nutrition and safety. Despite its importance, there is limited research focused on the comprehensive evaluation of the nutritional and microbial quality of frozen marine fish in Kano State and how these quality parameters vary among stations/retail outlets, especially due to handling and storage conditions, which are usually different from one station to another. This study aims to fill this gap by assessing the nutritional composition and microbial contamination of selected frozen marine fish species sold in selected LGAs of Kano State, Nigeria.

Materials and methods

Sampling area

The research was carried out in selected local government areas from the Sudan Savannah ecological zone of Kano State, and purposive sampling was used to select three peri-urban local government areas namely Bichi, Dambatta and Gwarzo Local Government Areas.

Sampling size and procedure

Three (3) most commonly sold frozen marine fish in the study areas were used. A total of eighty-one (81) samples comprising twenty-seven (27) each of Atlantic herring (*Clupea harengus*), Atlantic mackerel (*Scomber scombrus*) and Atlantic horse mackerel (*Trachurus trachurus*) were sampled/purchased from the three sampling areas (Bichi, Dambatta and Gwarzo). The collection of the samples was done three times from each sample station. The first collection was done at the arrival of the stocks/products, the second collection was done four days after the first collection, while the third collection was done when their stocks were about to finish. All the sample stations have gotten their stocks from the same company in Lagos State and Rivers State, Nigeria. The fish samples were collected into sterile tinfoil paper individually and immediately transported in an ice cooler/cold flask to retain the freshness to Umaru Musa Yar'adua University (UMYU), Katsina State, Nigeria, at the Biochemistry laboratory and Microbiology laboratory for analysis of proximate compositions and microbial load, respectively. The fish were thawed in the laboratory using the control water submersion method.

Laboratory analysis

Proximate compositions of the fish sample were analysed using the method of analysis by the Association of Official Analytical Chemists (International. Association of Official Analytical Chemists, 2016). The Free Fatty Acids were analysed using the Titration Method in Crude and Refined Oils (International. Association of Official Analytical Chemists, 2012). Mineral components were evaluated from the solution obtained by first wet-ashing the samples and dissolving the ash with de-ionised water and concentrated hydrochloric acid in a standard flask. The solution was analysed for mineral content using an Atomic Absorption Spectrophotometer. Phosphorus was analysed by employing the method of Vanado Molybate and read on a colourimeter (Santoso et al., 2006). Microbial analysis was determined using standard microbiological procedures (Alkuraieef et al., 2022).

Data analysis

Data was presented using descriptive statistics, then subjected to normality and homogeneity of variance tests, after which a Two-way analysis of variance was used to compare each parameter among the fish species and the sampling stations at 95% level of probability ($p<0.05$). The use of Two-way ANOVA was necessary because there are two sources of variation, which were the species and the stations. Whenever a significant difference was observed, Turkey's HSD test was used to separate the different means using IBM SPSS Version 23.

Results and discussion

The result of the proximate compositions of *C. harengus*, *S. scombrus* and *T. trachurus* is shown in Table 1. The highest crude protein, 21.51 ± 0.53%, was recorded in *T. trachurus* from Dambatta, while the least, 15.28 ± 0.38%, was recorded in *C. harengus* from Bichi. Crude protein was significantly higher ($p<0.05$) in *T. trachurus* than in other species, but there was no significant difference ($p>0.05$) among the stations. The highest free fatty acids content, 2.07 ± 0.18%, was observed in *T. trachurus* from Gwarzo, while the least, 0.78 ± 0.12%, was recorded in *S. scombrus* from Dambatta. Free fatty acid was higher in *T. trachurus,* and it was significantly different ($p<0.05$) from other species.

Table 1. Proximate and free fatty acids compositions of three frozen marine fish species sold in selected local government areas of Kano State.

Overall stations and fish species					Two-way ANOVA		
Parameters (%)	Stations	*C. harengus*	*S. scombrus*	*T. trachurus*	Species (p value)	Stations (p value)	Species * Stations (p value)
Moisture	BCH	75.59 ± 1.81^{a}	71.76 ± 1.20^{b}	69.80 ± 1.05^{c}	0.000	0.220	0.000
	DBT	74.44 ± 2.53	73.17 ± 0.47	68.66 ± 0.65			
	GRZ	73.61 ± 1.77	74.46 ± 0.94	70.19 ± 0.65			
Crude protein	BCH	15.28 ± 0.38^{c}	20.67 ± 1.56^{b}	20.03 ± 1.58^{a}	0.000	0.726	0.000
	DBT	18.07 ± 0.48	16.52 ± 1.49	21.51 ± 0.53			
	GRZ	17.76 ± 0.64	18.04 ± 1.05	19.66 ± 0.96			
Crude lipid	BCH	4.70 ± 1.14^{ab}	4.07 ± 0.29^{b}	4.70 ± 0.40^{a}	0.046	0.106	0.664
	DBT	3.71 ± 1.41	3.93± 0.89	4.44 ± 0.65			
	GRZ	4.31 ± 1.13	4.26 ± 0.43	4.84 ± 0.40			
Total ash	BCH	2.33 ± 0.15^{b}	2.31 ± 0.36^{b}	2.72 ± 0.21^{a}	0.000	0.623	0.064
	DBT	2.15 ± 0.46	2.45 ± 0.26	2.76 ± 0.11			
	GRZ	2.42 ± 0.36	2.18 ± 0.28	2.58 ± 0.22			
Carbohydrate	BCH	$2.17 \pm 0.56^{B,b}$	1.24 ± 0.61^{b}	2.75 ± 0.54^{a}	0.000	0.000	0.000
	DBT	1.40 ± 0.95^{A}	1.91 ± 0.51	2.54 ± 0.55			
	GRZ	1.99 ± 0.69^{B}	1.07 ± 0.79	2.77 ± 0.29			
Free fatty acid	BCH	$0.92 \pm 0.19^{A,c}$	1.27 ± 0.15^{b}	2.03 ± 0.10^{a}	0.000	0.000	0.008
	DBT	0.89 ± 0.17^{B}	0.78 ± 0.12	1.72 ± 0.25			
	GRZ	0.87 ± 0.23^{C}	1.16 ± 0.35	2.07 ± 0.18			

*Values are presented as the means ± standard deviation. *Different small letters as superscripts across the rows indicate significant differences ($p<0.05$) among the fish species. *Different capital letters as superscripts within the column for each parameter indicate significant differences ($p<0.05$) among the stations. Key: BCH – Bichi; DBT – Dambatta; GRZ – Gwarzo.

In this study, all the proximate composition parameters were affected by the species, but not the collection stations. For instance, the highest amount of moisture was reported in *C. harengus* which was significantly higher than that of *S. scombrus* and *T. trachurus*. This is similar to the study of Bello et al. (2019) who studied the nutritional qualities of *C. harengus*, *T. trachurus*, *S. scombrus* and *M. undulates*. In addition, *T. trachurus* had reported higher protein content, lipid, total ash and estimated carbohydrate. The result is in line with the study of Babalola et al. (2011), who reported differences in proximate composition of marine and freshwater fish species (*S. scombrus, T. trachurus, S. aurita, M. furnieri* and *C. gariepinus*) and concluded that species of fish influence the proximate composition. However, Padmavati (2017) reported *S. scombrus* to have higher protein content over *T. trachurus and C. harengus*. The variation in proximate composition also occurs within the same species depending upon the fishing ground, age and sex of the individual, geographical location of catch, environmental circumstances, sexual maturity, size and reproductive status of the fish. Understanding this may assist in determining the suitability of different species to specific processing and storage methods (Malik et al., 2021).

Free fatty acid composition was affected by the species and the collection station. For instance, the highest amount of free fatty acids was reported in *T. trachurus,* which was significantly higher than that of *S. scombrus* and *C. harengus*. This is in line with the observation of Fawole et al. (2018) who also reported differences in free fatty acids composition of frozen marine fish species (*Sardinella* spp. and *M. poutassou*). The differences observed in the free fatty acids composition values from different stations may be due to the duration of freezing storage and different methods of handling (Alkuraieef et al., 2020). The free fatty acids in the samples studied were within the FAO recommended level of 2.5% for consumption (Food and Agriculture Organization, 2023).

The results of the mineral compositions of *C. harengus, S. scombrus* and *T. trachurus* are shown in Table 2. The highest Na content (1.69 ± 0.65 mg Kg^{-1}) was observed in *C. harengus* from Bichi, while the least content (0.38 ± 0.07 mg Kg^{-1}) was recorded in *S. scombrus* from Dambatta. Generally, the Na was higher in *C. harengus* and was significantly different ($p<0.05$) from other species, but the differences due to station were not significant ($p>0.05$). However, there was significant interaction ($p<0.05$) between the species and stations of collection. The Ca content of 1.24 ± 0.51 mg Kg^{-1} was recorded in *S. scombrus* from Bichi and was the highest, while 0.12 ± 0.01 mg Kg^{-1} was observed in *C. harengus* from Bichi and it was the lowest. The Ca was significantly higher ($p<0.05$) in *S. scombrus* than the other species, but the differences were not significant among the stations ($p>0.05$). There were no significant ($p>0.05$) interactions in Ca between the stations and the species.

Table 2. Mineral compositions of three frozen marine fish species sold in selected local government areas of Kano State.

Overall stations and fish species					Two-way ANOVA		
Parameters (mg Kg^{-1})	Stations	*C. harengus*	*S. scombrus*	*T. trachurus*	Species (p value)	Stations (p value)	Species * Stations (p value)
Sodium (Na)	BCH	1.69 ± 0.65^{a}	0.39 ± 0.07^{b}	0.50 ± 0.08^{b}	0.000	0.144	0.008
	DBT	1.44 ± 0.67	0.38 ± 0.07	0.51± 0.08			
	GRZ	1.05± 0.66	0.39± 0.05	0.52± 0.09			
Calcium (Ca)	BCH	0.12 ± 0.01^{b}	1.24 ± 0.51^{a}	0.14 ± 0.03^{b}	0.000	0.537	0.077
	DBT	0.13 ± 0.04	1.17 ± 0.43	0.14± 0.03			
	GRZ	0.15± 0.04	0.95± 0.43	0.15± 0.03			
Potassium (K)	BCH	0.64 ± 0.21^{a}	0.52 ± 0.12^{b}	0.56 ± 0.14^{b}	0.004	0.354	0.372
	DBT	0.69 ± 0.19	0.49 ± 0.09	0.58± 0.15			
	GRZ	0.70± 0.19	0.58± 0.16	0.61± 0.14			
Iron (Fe)	BCH	0.68 ± 0.12^{a}	0.82 ± 0.43^{b}	0.63 ± 0.22^{b}	0.000	0.081	0.000
	DBT	0.93 ± 0.18	0.35 ± 0.28	0.50± 0.05			
	GRZ	0.98± 0.09	0.61± 0.17	0.56± 0.13			
Manganese (Mn)	BCH	0.23 ± 0.06^{c}	0.22 ± 0.05^{b}	0.35 ± 0.03^{a}	0.000	0.103	0.003
	DBT	0.19 ± 0.06	0.24 ± 0.03	0.39± 0.02			
	GRZ	0.18± 0.06	0.28± 0.04	0.41± 0.05			

*Values are presented as the means ± standard deviation. *Different small letters as superscripts across the rows indicate significant differences (p <0.05) among the fish species. *Different capital letters as superscripts within the column for each parameter indicate significant differences (p <0.05) among the stations. Key: BCH – Bichi; DBT - Dambatta ; GRZ – Gwarzo

The potassium content (K), 0.70 ± 0.19 mg Kg^{-1}, was recorded in *C. harengus* from Gwarzo, while the lowest content, 0.49 ± 0.09 mg Kg^{-1}, was recorded in *S. scombrus* from Dambatta. K was significantly higher ($p<0.05$) in *C. harengus* than in other species, but there was no significant difference ($p>0.05$) due to station. The interaction between species and stations were not significant ($p>0.05$). The highest Fe content, 0.98 ± 0.09 mg Kg^{-1}, was recorded in *C. harengus* from Gwarzo, while the least, 0.35 ± 0.28 mg Kg^{-1}, was recorded in *S. scombrus* from Dambatta. Fe was significantly higher ($p<0.05$) in *C. harengus* than in other species, but there was no significant difference ($p>0.05$) due to station and in the interaction between species and stations.

All the mineral compositions in this study were affected by the species but not the collection station. For instance, the highest amount of sodium was reported in *C. harengus,* which was significantly higher than that of *S. scombrus* and *T. trachurus*. Furthermore, the highest amount of calcium was reported in *S. scombrus,* which was significantly higher than that of *T. trachurus* and *C. harengus*. The highest amount of manganese was reported in *T. trachurus* which was significantly higher than that of *S. scombrus* and *C. harengus*. This is similar to the observation of Egerton et al. (2020) on *C. harengus*, *C. aper* and *M. poutassou.* The mineral compositions in this study varied significantly among the species. This may be due to the fact that variations in concentrations of these mineral elements vary from one species of fish to another and also due to the chemical forms of the elements and their concentrations in the local environment (Babalola et al., 2011).

The results of the microbial population/abundance in *S. scombrus, C. harengus* and *T. trachurus are* shown in Table 3. The highest amount of *Salmonella sp* (4.22 ± 2.54 x 106cfu g^{-1}) was observed in *T. trachurus* from Dambatta, while the least (0.56 ± 0.53 x 106cfu g^{-1}) was recorded in *S. scombrus* from Dambatta. Generally, the *Salmonella sp* was higher in *T. trachurus* and was significantly different ($p<0.05$) from other species, but the difference in *Salmonella sp* due to station was not significant (p>0.05). However, there were significant interactions (p<0.05) between the species and stations of collection. The *E. coli* of 3.22 ± 1.99 x 10^6cfu g^{-1} recorded in *S. scombrus* from Dambatta was the highest, while 1.00±0.87x10^6cfu g^{-1} observed in *S. scombrus* from Gwarzo was the least.

Table 3. Microbial population of the three frozen marine fish species sold in selected local government areas of Kano State.

Overall stations and fish species					Two-way ANOVA		
Parameters (x10^6cfu g^{-1})	Stations	*C. harengus*	*S. scombrus*	*T. trachurus*	Species (p value)	Stations (p value)	Species * Stations (p value)
Salmonella spp	BCH	0.67 ± 0.50^b	2.00 ± 1.58^b	1.22 ± 0.67^a	0.000	0.060	0.000
	DBT	0.56 ± 0.53	0.78 ± 0.83	4.22 ± 2.54			
	GRZ	1.00 ± 1.12	1.22 ± 0.83	1.00 ± 0.87			
E. coli	BCH	1. 89 ± 1.05^{ab}	2.00 ± 1.73^a	1.33 ± 1.00^b	0.037	0.114	0.044
	DBT	1.56 ± 1.13	3.22 ± 1.99	1.11 ± 0.93			
	GRZ	1.67 ± 1.12	1.00 ± 0.87	1.11 ± 0.93			
Total coliform	BCH	3.67 ± $2.03^{A,a}$	2.11 ± 2.03^{ab}	1.11 ± 1.17^b	0.003	0.046	0.013
	DBT	1.56 ± 1.01^{AB}	2.56 ± 2.74	0.67 ± 0.50			
	GRZ	2.22 ± 0.71^B	0.33 ± 0.71	1.22 ± 1.30			
Mold	BCH	4.89 ± 4.89^a	4.89 ± 1.96^{ab}	3.56 ± 2.35^b	0.040	0.384	0.283
	DBT	4.22 ± 2.82	3.78 ± 1.99	2.78 ± 1.48			
	GRZ	5.78 ± 3.42	2.78 ± 2.44	3.89 ± 1.62			

*Values are presented as the means ± standard deviation. *Different small letters as superscripts across the rows indicate significant differences (p <0.05) among the fish species. *Different capital letters as superscripts within the column for each parameter indicate significant differences (p <0.05) among the stations. Key: BCH – Bichi; DBT – Dambatta; GRZ - Gwarzo.

The *E. coli* was significantly higher (p<0.05) in *S. scombrus* than in the other species, but it was not significantly different among the stations (p>0.05). There were significant (p<0.05) interactions in *E. coli* between the stations and the species. The Total coliform, 3.67 ± 2.03 x 10^6cfu g^{-1} was recorded in *C. harengus* from Bichi, while the least, 0.67 ± 0.50 x 106cfu g^{-1} was recorded in *T. trachurus* from Dambatta. Total coliform was significantly higher (p<0.05) in *C. harengus* than in other species, but the difference in total coliform due to station was not significant (p>0.05). However, the interaction between species and stations was significant (p<0.05). The highest mold, 5.78 ± 3.42 x 106cfu g^{-1}, was recorded in *C. harengus* from Gwarzo, while the least, 2.78 ± 1.48 x 106cfu g^{-1}, was recorded in *T. trachurus* from Dambatta. Mould was significantly higher (p<0.05) in *C. harengus* than in other species, but there was no significant difference (p>0.05) due to stations and in the interaction between species and stations of collection.

In the present study, all the microbial load parameters were affected by the species but not the collection station. The highest amount of microbial load was reported in *C. harengus,* which was significantly higher than that of *T. trachurus* and *S. scombrus.* This is similar to the observation of Adeparusi et al., (2019) who reported differences in bacteria loads of marine water fish species (*C. harengus, S. scombrus and M. poutassou*). Taiwo et al. (2017) also reported differences in bacterial loads of marine water fish species *T. trachurus, S. scombrus, L. crocea, G. chalcogrammus and O. niloticus*. The variations in the bacterial loads for the fish species studied are an indicator that handling and storage methods employed by the fish vendors might be different (Olutimehin et al. 2019). It is also possible that the different species of fish have different levels of susceptibility to microbial attack and growth. The microbial load recorded in this study did not exceed the recommended limit of x10^6 to 10^7cfu g^{-1} of bacteria load

Conclusion

The proximate composition varied among the species but most of the parameters were not affected by station. The free fatty acid was influenced by both the species of fish and stations. However, they were all within the recommended levels. The mineral composition and microbial loads of these fish species were also affected by the fish species. *T. trachurus* had the best proximate compositions and the least microbial load among the experimented fish species, all the fish species had proximate and microbial loads within the safety levels for human consumption.

Data availability

Data is available with the corresponding author and it will be made available on request.

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